THE EXPLOSIVES ENGINEER

FORE-RUNNER OF PROGRESS IN
MINING-QUARRYING & CONSTRUCTION

JULY-AUGUST · 1960

VOLUME 38-NUMBER 4

HERCULES® ELECTRIC BLASTING CAPS HELP SET WORLD'S RECORD IN TUNNEL DRIVING

"Setting a world's record," says Clancy O'Dell, project manager of the recently holed-through New York City's West Delaware Tunnel, "is largely a combination of loyal skilled tunnel workers and the best and most dependable equipment and supplies." And he should know, for the boring of this 43.64-mile-long water tunnel was finished in the record time of 841,000 man-days, or ten months ahead of schedule.

On this project, the West Delaware Tunnel Constructors also drove a record 2,177 linear feet in a single 31-day period and established a shaft-sinking record of 243 linear feet for a like period.

Hercules® Short-Period Delay Electric Blasting Caps, used almost exclusively in all phases of blasting activity on the West Delaware Tunnel, proved their dependability and efficiency in helping to establish these records.

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THE EXPLOSIVES ENGINEER

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Forerunner of Progress in Mining, Quarrying, Construction

We were saddened to learn of the sudden death from a heart attack on July 8 of Lewis Nordyke, author of "Blasting the Intermountain Roberts Tunnel" which begins on page 103. Mr. Nordyke, a frequent contributor to these pages, was a native of Texas where he lived until his death, and the author of five books and many articles, most of them about his home state. One, *Nubbin Ridge*, will be published posthumously by Doubleday in September. Born in 1905 on a farm near Cottonwood, Texas, he graduated from the University of Missouri School of Journalism in 1933, and two years later married a fellow student, Dorothy Beeman of Amarillo. At the time of his death he had just completed several articles for THE EXPLOSIVES ENGINEER. Among these, which will appear in subsequent issues, are an article on Glen Canyon Dam, the U. S. Steel coal operations in Utah, and the Western Gold & Uranium's Orphan Mine in Arizona.

The holing-through of the Roberts Tunnel was a triumph of men with knowledge, skill, and purposeful determination over the whims of a perverse mother nature.

Few tunnels have been driven through an area where so many different challenges were met and overcome. Bad earth, high-pressure water, and the Rockies trying to settle down and squeeze into the tunnel were some of the problems that taxed the ingenuity and patience of the staff of the Blue River Constructors.

This 23-mile tunnel, which will transport water from the western side of the Continental Divide to Denver on the east side, and the many problems encountered in its building are described by Lewis Nordyke in an article starting on page 103.

EDITORIAL STAFF: JAMES J. O'NEILL, *Editor*; THOMAS E. MILLER, *Associate Editor*; GERTRUDE A. DONNELLY, *Associate Editor*; EDWARD L. GRANT, *Art Editor*; HOWARD B. DICKSON, *Production Manager*; A. J. ACKERMAN, *Advertising Manager*; MONTGOMERY R. BUDD, *Director*.

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Views and opinions expressed by the authors of articles in this publication are their own, and they do not necessarily represent those of the publisher.

Back in the early 1880's, Jefferson, at that time a thriving little community in North Carolina, was humming with activity. About 500 copper miners from this area were employed in taking copper out of the Ore Knob Mine, then one of the largest copper mines in the United States. In 1883 a declining copper price made it uneconomical to operate the mine and the owners were forced to close the property.

During the periods 1942-43 and 1953-54, the area was probed by diamond drills, first by the U. S. Bureau of Mines and later by Nipissing Mines Co. Ltd. of Canada. The cores indicated a plentiful reserve.

Dormant for many years, a more favorable price structure has reactivated this property, and once again the Ore Knob Mine, operated by Appalachian Sulphides, Inc., is a producing property.

J. R. Daniel, an explosives engineer, writes about this mine and details the drilling and blasting techniques in use. Please refer to his article on page 116.

• • •

It is amazing what fractional charges of dynamite can do on demolition jobs when the work is too delicate for the drop ball and too tough for the wrecking bar or chipper.

A recent demonstration of what a skilled technician can accomplish with dynamite was the removal of a loading platform at a food-packaging factory near Ellicott City, Maryland. Some of the difficulties that the blaster had to contend with were nearby oil-storage drums, machinery, an overhead door with windowpanes, electrical fixtures, switches, and conduits.

An illustrated report on this example of controlled blasting, by William F. Hallstead, begins on page 120.

GARDNER-DENVER OPENS A NEW ERA IN PERCUSSION DRILLING

No other rock drill compares with

THE NEW GARDNER-DENVER

No other rock drill gives your operator absolute and independent control of these vital rock drill functions:

Rotation without impact—Efficient gear motor supplies powerful rotation in either direction, even when drill is not impacting. Three rotation speeds at the flick of a control. Neutral position stops rotation.

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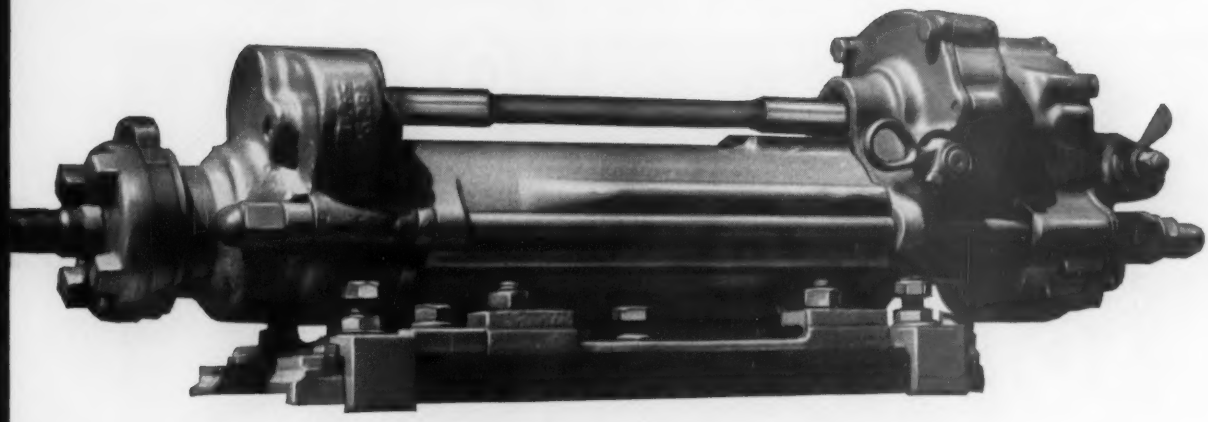

POWER ROTATION MODEL PR123

UP TO 30% FASTER PENETRATION

The new PR123 is the only rock drill which uses *all* hammer energy directly for percussion. There's no rotational drag on the piston hammer. Every blow is sharp and solid. Results: faster hard rock drilling than ever before. Depth of hole does not affect drilling speed as it does with a conventional rifle-bar-rotated drill. You can drill deeper holes with the PR123.

SELECTIVE DRILLING

Now your operator can line up the right combination of rotation speed, impact force, feed pressure and hole blowing for fast drilling in any type of rock. No other rock drill provides absolute, independent and instantaneous control of impact and rotation. Drilling action can be changed as soon as the bit enters a new rock formation.

NO ROTATION PARTS IN CYLINDER

The PR123 has no rifle bar, no ratchet ring, no pawls or other vulnerable internal rotation parts, and thus eliminates the most frequent causes of rock drill breakdown and maintenance. Instead, rotation is supplied by a long-wearing gear motor which is efficiently lubricated by the air line oiler. A torsion bar absorbs rotational shock between shank and motor.

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Independent rotation control is a real time-saver when drilling with sectional rods and couplings. Rotation without impact permits power coupling of threaded rods without damage to the threads. Reverse rotation speeds uncoupling when coming out of the hole. Independent power rotation also helps free stuck steel.

PROVEN DESIGN—The new PR123 uses the same cylinder and automatic valve parts as the popular Gardner-Denver DH123. Renewable chuck driver liners for all sectional shanks. Piston diameter: 4½". Length: 38½". Weight, less mounting: 290 pounds.

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RICHARD W. WHITNEY

Richard W. Whitney

EXECUTIVE VICE PRESIDENT, MINING OPERATIONS

THE HANNA MINING COMPANY

A Biography

Few people have achieved more in the mining industry than Richard W. Whitney, executive vice president of The Hanna Mining Company. Dick was born on a farm in Stewartville, Olmsted County, Minnesota, on the fifth day of the twentieth century. That unusual circumstance of timing may have set his life's pattern, for he says he has always been lucky in timing. Maybe following General Nathan Forrest's military maxim, "git ther fustest with the mostest," will give one the advantage, but timing is not the whole story; you must have "the mostest" when the fracas starts. Dick evidently had something besides fortunate timing.

His father, Ralph W. Whitney, and his mother, Carrie, emigrated from Maine to Wisconsin, and thence to Minnesota in the late 1890's. Dick began his education in the country school at Stewartville and subsequently attended Rochester, Minnesota, High School, from which he graduated with a creditable record in football and basketball. Then he went on to the University of Minnesota, where he studied civil engineering.

The tragic depression of the twenties with its ruinous decline in farm prices brought an end to Dick's academic career before he graduated, so that he started to work with Butler Brothers at Cooley, Minnesota, as an engineer's helper. He stayed with this organization twenty-four years, all of them spent in its various iron-mining operations. In this time he progressed through the jobs of ore inspector, washing plant foreman, assistant chief engineer, superintendent, and finally general superintendent, before he left Butler's to go with The M. A. Hanna Company as general superintendent of its Minnesota operations. Now, by the happy circumstance of the consolidation of Butler's and Hanna, he is back with his old buddies from the range.

His progress with Hanna has been solidly based on the mining experience he gained in his years with Butler's, and the fund of mining knowledge that has attracted the attention of other mining companies who look at the rising star of Hanna in iron mining. Measured in terms of tonnage of ore alone, this rise has been spectacular. In 1944, Hanna shipped three million tons of ore from the range. By 1948, it was shipping 13 million tons. With the addition of the Canadian properties, Hanna, acting as agents for associated companies, increased its tonnage to 21.7 million tons in 1959, and the peak year of all was 28 million tons in 1957. Dick is vehement in saying he did not do this, but he looks with satisfaction on the organization he helped to create, which can be credited with this achievement in tonnage of ore shipped to the hungry steel mills of America.

A year after he came with Hanna, Dick was made general manager of mines in Minnesota of The M. A. Hanna Company, and moved to Cleveland. In 1957 he was made vice president of operations of The Hanna Coal and Ore Company, later changed to The Hanna Mining Company, and in May of this year he was advanced to executive vice president of The Hanna Mining Company, his present position.

Since he joined Hanna, his mining experience has been broadened to include the iron-mining areas of Michigan and Missouri and the nickel operations in Oregon. While he is familiar with Hanna's operations in Quebec-Labrador, that development has been largely the work of others in the Hanna organization.

In his years on the range he went in for a little duck hunting, and was a good enough wing shot to bring in a duck or two. He says he stays away from big game hunting because someone might deliberately mistake him for a buck.

In 1925, he married Kathryn Kiefer at Antigo, Wisconsin, and this marriage has been blessed with three children: Richard, Jr., who is now with The Hanna Ore Mining Company as assistant superintendent of the Mississippi Group Mine at Keewatin, Minnesota; Barbara, a dietician in the Borgass Hospital in Kalamazoo, Michigan; and John, now in college in St. Paul, Minnesota. The family lives at 13900 Shaker Boulevard, Cleveland, Ohio.

Dick is a member of the American Institute of Mining Engineers, and was chairman of the Minnesota Section about ten years ago, a member of the American Iron & Steel Institute, and of the Engineers' Club of Northern Minnesota. He is a member of the Kitchi Gammi Club of Duluth, the Minneapolis Club, the Minnesota Club of St. Paul, and the Algonquin Club of Hibbing, Minnesota.

Editorial

Safety Communications

The National Safety Council once more has chosen this magazine for its Public Interest Award for 1959. This award was established in 1948 to honor leadership, initiative, and originality in the furtherance of accident prevention by the mass media.

We feel honored that THE EXPLOSIVES ENGINEER has been chosen again as a recipient of one of these prizes, even though they are noncompetitive and are given to other organizations in the communications field. Perhaps understandably, we have always put great emphasis on the place of communications in the field of safety. Without it we believe the enviable safety records achieved by mines, quarries, and other explosives-consuming industries in the United States would have been impossible.

There is more to safety than the use of safety appliances and the adoption of safer work methods to avoid accidents. New devices and new methods can do much, but they are useless in the hands of unsafe workers.

Safety communications have at least three jobs to do, each of them as important as the material side of the problem. The first of these is instruction in the use of safety devices and methods. Without the teacher or the manual of procedure, the worker cannot put his new device to work.

Second, an even more important job of communications is the creation of a desire in the worker to work safely and avoid accidents. He must be persuaded to forego short cuts. Often the short cut is most attractive; where no danger is involved it is usually the best way to proceed. But in the mine or quarry or on a construction job, the short cut may lead to accidents that lurk unseen along the unorthodox path. Workers like short cuts, as most of us do, and they have many advantages: the reduction in costs; the saving in time and energy; the increased output made possible. All are attractive goals which, however, may not be achieved if gained only by sacrificing safety.

Third, the task of communications, particularly of the mass communications media to which this award is made, is to make safety popular. Safety of itself is likely to be dull, drab, and unexciting. Industry and the communications media together must make it fashionable to be a safe worker. Once we do that, we will have come a long way toward achieving our objective, the prevention of accidents.

Our Friend is Fifty

When your good friend reaches the age of fifty it is a time for congratulations and well-wishing. The miner's best friend, the Federal Bureau of Mines, having reached that signal point in its honorable career, deserves a heartfelt salute from the mining industry.

Unquestionably the Bureau's greatest achievement has been as a stern protector of the lives and limbs of hapless miners and quarrymen. Created at a time when mine accidents were killing an average of 364 men a year, or one miner a day, the Bureau's diligent mine safety campaign has reduced the toll to less than one-tenth. It has done this in many ways: through the advocacy of safety laws and regulations, through the recommendation of safety devices and practices, through research on the causes of fires, accidents, and death-dealing disasters.

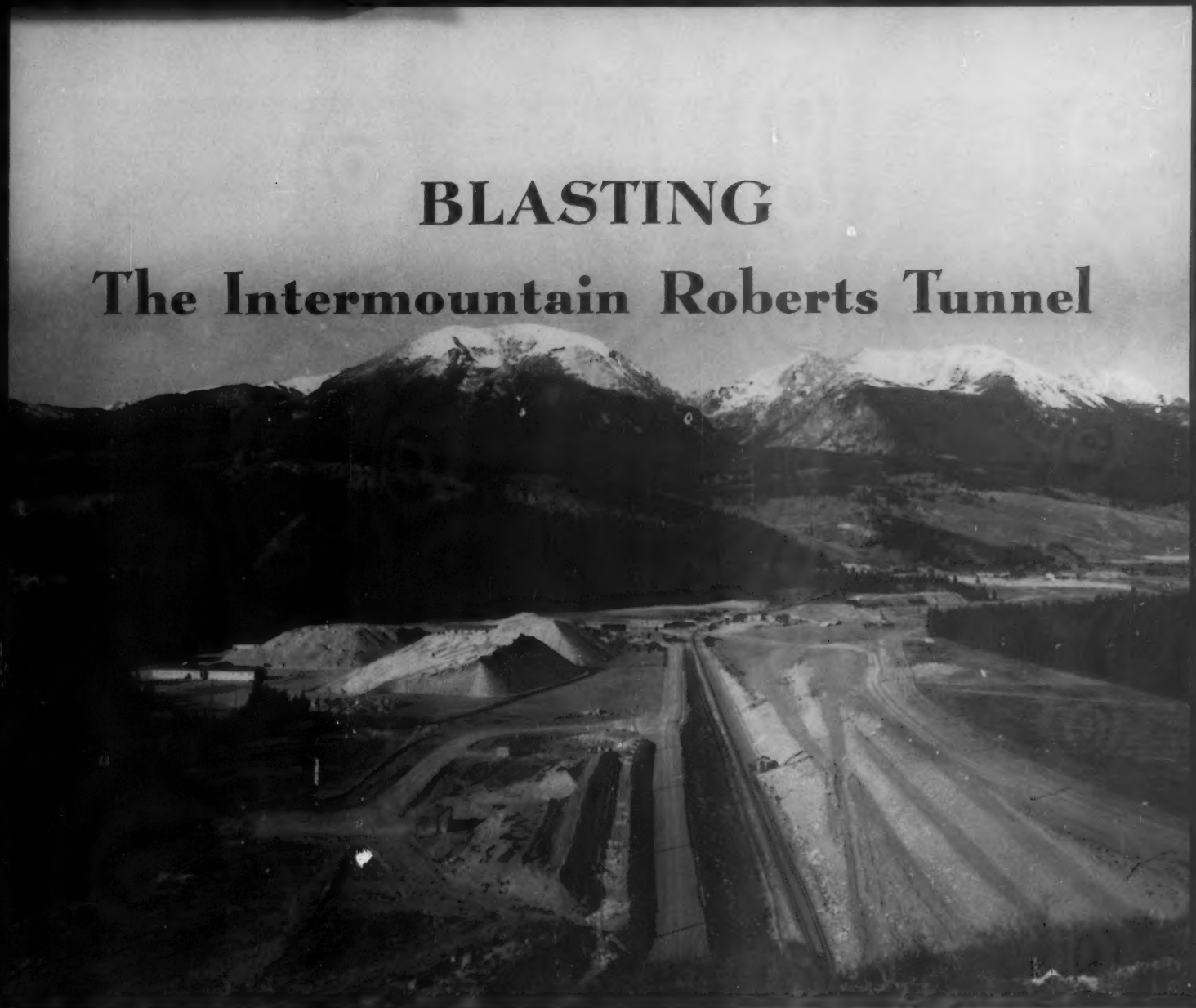
So outstanding is the Bureau's record of making mines safe, more by persuasion than by force, many are unaware of its enviable record in other directions. Research on coal-burning equipment has cut our electricity bill; Bureau studies in ventilation have benefited structures only remotely linked with mines, such as the Holland Tunnel under the Hudson; hospitals for years have been using radium extracted by the Bureau from domestic carnotite. American and many foreign businessmen lean heavily upon the statistics and analyses of domestic and foreign minerals published by the Federal Bureau in nearly 8,000 reports.

No supplier to the American mining industry is in a better position than the explosives industry to support the Bureau's contention that "there has never been an accident from a permissible explosive used in a permissible manner." Many a wrangle has occurred over what should be a permissible explosive, but for many years now no explosives maker has seriously questioned the wisdom of the Bureau's compilation of a list of permissible explosives.

With a fervent "thank you" to the miner's friend, we offer our heartiest congratulations to the Bureau as it begins its second half century of service to the nation's mines and quarries.

BLASTING

The Intermountain Roberts Tunnel



BEAUTIFUL BUT DEFIANT: Despite the beauty and serenity of the country, the contractors had to fight nature for every foot of tunnel advance. This photo shows the west portal area near Dillon, Colorado.

This 23-mile tunnel through the Continental Divide will bring water from the western side of the Rockies to meet the needs of Denver's growing population

LEWIS NORDYKE*

A great moment came thundering in for the Denver Water Board when a charge of dynamite was detonated under a craggy peak in the Rocky Mountains last February 24. The time was 12:36 o'clock on a chilly afternoon. Standing back at a safe distance in a dimly lighted tunnel were members of the Water Board and other dignitaries, all of them in high boots, rubber trousers, slickers, and hard hats. Their glasses were foggy; they were puffing a little. Some of these men were a bit nervous about being 14 miles back in the innards of Landslide Mountain which stood 4,500 ft. above them; only an event of great importance would have enticed them into a man-trip train for a jostling ride to the place where they now stood waiting anxiously for the big moment.

The switch was pulled and the

*Deceased July 8, 1960

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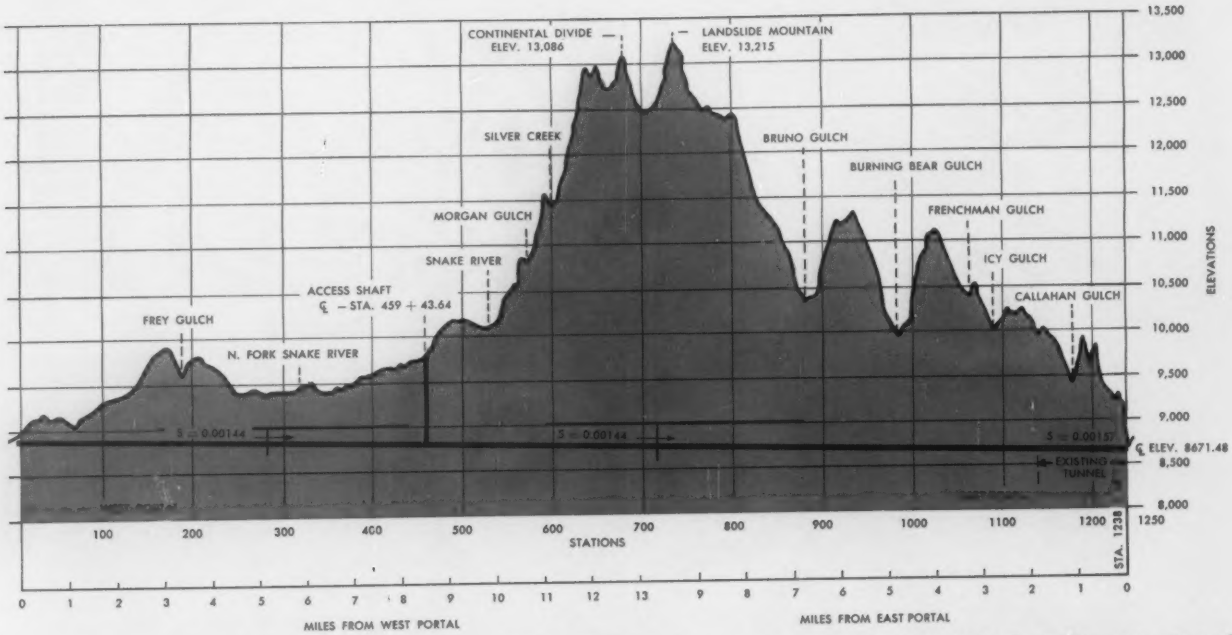
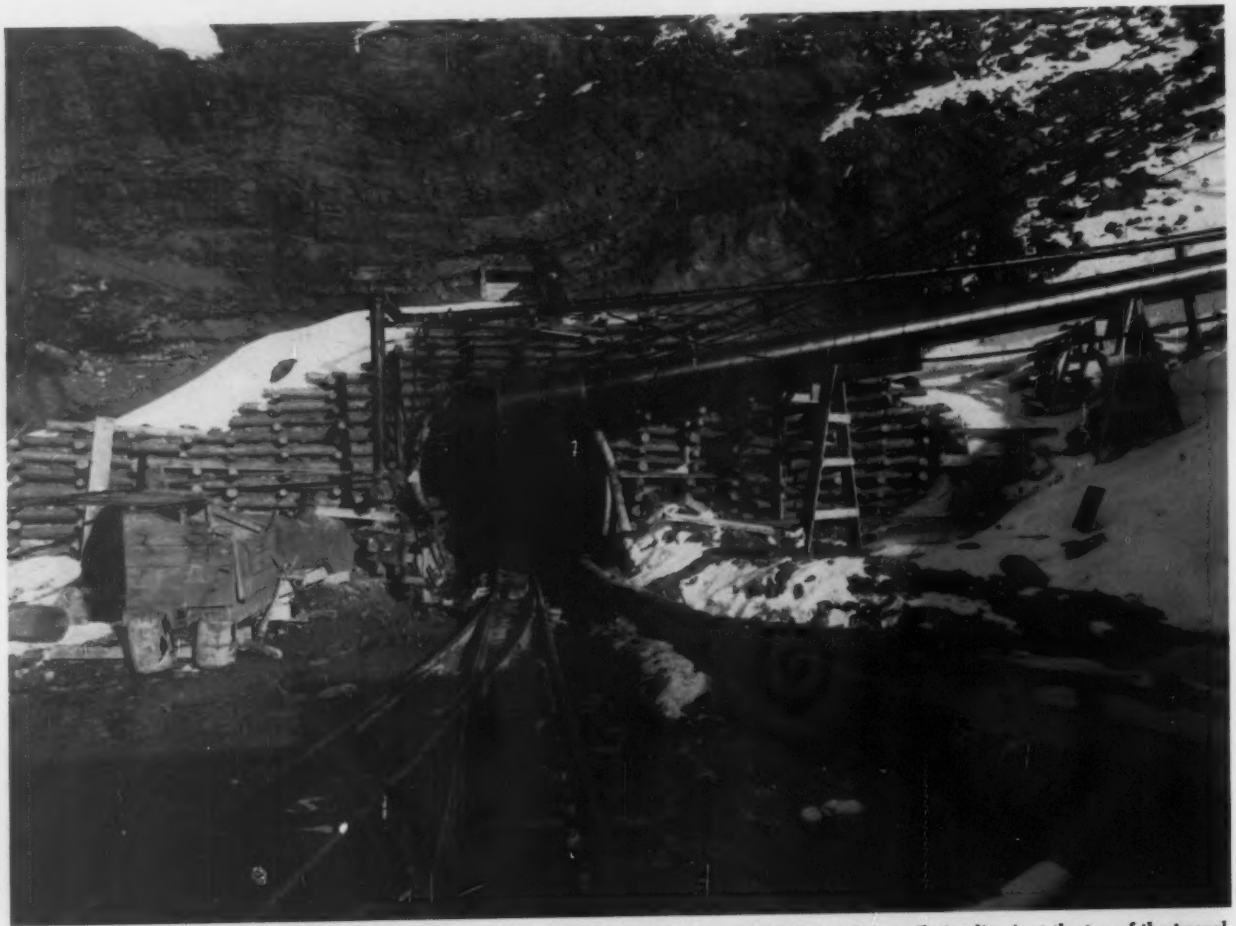


TUNNEL PROFILE: This schematic drawing of the 23-mile Harold D. Roberts Tunnel shows its line through the Rocky Mountains west of Denver. The tunnel drop from west to east averages 1.45 ft. per 1,000 ft., a total drop of 178 ft. in the entire length.

(Drawing, courtesy Blue River Constructors)



WEST PORTAL: The west portal of the Roberts Tunnel was started at an elevation of 8,849 ft. The ventilating line is at the top of the tunnel, while the lower pipe is the water-discharge line.

DRILL ROUND: Drilling was done from a jumbo which mounted four drills. The depth and pattern of the holes were determined by the type of material being blasted. Nearly every drill round was different.

round fired. The muck rattled down. There was a swift movement of the air. When the dust and smoke cleared, the visitors could see miles down the tunnel. This was the final holing-through of the renowned Harold D. Roberts Tunnel, which, in a good many ways, is a feat of engineering and blasting to stagger the imagination. It is a good example of how man, with courage and know-how, can conquer mountains and correct the mishap of misplaced rain.

Driving the bore was considerably less than a picnic, what with bad earth, high-pressure water, and the Rockies trying to settle down and squeeze into the tunnel.

The tunnel extends from near Dillon to Grant in Colorado. It is 23.3 miles long. In places, as at the point of holing-through, it is 4,500 ft. beneath the surface. It is probably the longest tunnel ever driven from four headings—one from each portal and two from an access shaft. At least 1,075,000 cu. yd. of material was blasted and hauled out. In the rough, the horseshoe-shaped bore is 12 ft. 6 in. in diameter; when lined with concrete, which will be completed by January, 1962, the waterway will have a diameter of 10 ft. 3 in.

It will convey water from the western to the eastern slope of the Continental Divide. A lake being created at Dillon to impound water from the Blue River (a tributary of the mighty Colorado), the 14-mile-long Snake River, and the Ten-Mile River will feed into the tunnel. It has been designed to operate under pressure, with the west portal lying in the reservoir being created by Dillon Dam, an earth-fill structure. The tunnel will carry 788 sec.-ft. of water with a Dillon Reservoir high water mark of 8,886 ft. above sea level; it will carry 1,020 sec.-ft. with a reservoir high of 9,017 ft. This new resource is reckoned to take care of Denver's water needs the remainder of this century.

At the east end of the tunnel, the water will spill into the north fork of the South Platte River and then flow by natural stream channel 46 miles to the intake facilities of the Denver water system, some 25 miles southwest of the city. The distance the water will travel from the reservoir to the center

of Denver's distribution system will be 94 miles, quite a way for a drink of water to trickle.

Denver's Bold Step

The project is a big part of a $101,000,000 water development program. It was necessary because Denver, the biggest city of the Mountain West, didn't have sufficient water for its explosive growth; moreover, nature fixed things so that there is not sufficient snow to meet demand on the eastern side of the mountains, and Denver had to hole through to the western side where the snow piles up in great white abundance.

Many American metropolitan areas face growing water problems. All of them haven't taken the bold steps of Denver, but eventually they will have to go into action or else face the prospect of perpetual drought. Therefore, within the next decade or so, there is apt to be a mighty lot of tunnel driving. California already has some big projects under way. A water supply looks good, and wet, to a city with a threat of future thirst.

To the members of the Denver Water Board, the Roberts Tunnel—when that final round was fired—was more than a hole through the mountains; rather, it was the realization of a long dream. For almost half a century Denver had been planning, struggling, and putting up money to open an effective channel from the western slope to the east side. The tunnel alone, when concreted and necessary equipment installed, will cost around $50,000,000. The cost is high, principally because rotten earth and high-pressure water necessitated a tremendous amount of grouting and the use of much more steel than was anticipated.

Blue River Constructors, a joint venture, is the contractor. This concern is made up of Mid-Valley, Inc., of Houston, Texas; S. A. Healy Company of Chicago, Illinois; J. A. Jones Construction Company of Charleston, North Carolina; Charles H. Tompkins Company of Washington, D. C.; A. S. Horner Construction Company, Inc., of Denver, Colorado; and Colorado Constructors, Inc., also of Denver. Mid-Valley is the sponsor, or managing partner, with L. H. Durst, vice president of Mid-Valley, responsible. T. F. (Ted) Adams is the project manager, in actual charge of the work.

WATER TROUBLE: There was a lot of water trouble in driving the tunnel. Here is shown water flowing under extremely high pressure from diamond drill holes made for grouting operations.

Rugged Terrain and Weather

It has taken a world of know-how and learn-how resourcefulness to drive the long bore. In the first place, the country is rough, wild, and scenic. The Continental Divide, which the tunnel punctures, rises 13,086 ft. in the blue Colorado sky; Landslide Mountain, highest elevation through which the bore was driven, towers 13,215 ft. At Dillon, or west portal, the elevation is 9,000 ft.; the tunnel starts at an elevation of 8,849.79 ft. and the east portal at Grant is 8,671.48 ft. above sea level. The drop from west to east is 178 ft., or a downgrade average of about 1.45 ft. per 1,000 ft. The lowest overburden is 400 ft.

The main headquarters office is at the west portal near Dillon. Before the project started, Dillon was a quiet, scenic little town of 250 population. It is in Summit County, the seat of which is Breckenridge, a fabled mining town of silver, lead, and gold. Many an old prospector searched for his burro in this country.

Dillon is 77 miles west and a bit south of Denver. The main highway between Denver and Dillon is over historic Loveland Pass, where a snowstorm can whip up without notice during the long winter season. The Dillon area, which is up some 9,000 ft., has an average of 200 in. of snow a year. When weather is discussed in this camp and a man says he thinks it will clear up, he means that the snow is apt to be clear up to the top of his pants. The winter is cold. The temperature has dropped to 37 degrees below zero. However, snow and cold cannot hinder in the tunnel, where the temperature is about 80.2°F.

The rugged area is covered with spruce, pine, aspen, and other timber and looks like a storybook alpine land in summer and winter. Out in the timber there are deer, black bear, elk, noisy coyotes that can get a good view of the moon on clear nights.

The wild animals were seldom bothered by the sounds of man until Blue River Constructors began moving in and banging around. The contract was let on July 12, 1956, and there was a mighty buzz in the mountains. Workmen and their families rolled in. The company brought in trailer houses and established a park.

MORE WATER: The difficulties involved by the extremely bad water conditions taxed the resourcefulness of Blue River's men. A slow-up in the tunnel advance, and attendant added cost, was quite serious.

Some of the workmen live in Dillon, Breckenridge, and as far away from headquarters as Fairplay, a town widely known for its marble tribute to Prunes, the renowned burro of hopeful prospectors. On the east end of the tunnel, workmen live at Grant, a very small village, and thereabout.

Roads were cleared, graded, and surfaced. Offices, shops, warehouses, compressor stations went up. Equipment rumbled in. Blue River Constructors made ready for a six-year job.

Four Headings

Because the tunnel would be over 23 miles in length, entailing a long haul of waste if it were driven from the two portals toward the center, a decision was made to sink an access shaft and drive both ways from there, giving the four headings. In that country a shaft can't be sunk just any place, because of the surface terrain and the underground geology. By exhaustive exploration, including diamond drilling, a site for the shaft was located 8.5 miles east of the west portal. Because of bad earth known to exist deep underground and also because it was impossible to sink the shaft in the direct line between portals, there are "dog-legs" in the tunnel. There are three major courses with horizontal angles of 9 degrees 4 minutes and 26 degrees 26 minutes located 5.42 miles and 8.69 miles east of the west portal.

The first actual excavation had been handled by construction forces of the Water Board; this had begun in June of 1946 and continued to July, 1956, at the east portal. A total of 9,986 ft. had been excavated when Blue River was given the contract.

Blue River started work on the access shaft on October 3, 1956. Excavation began at the west portal on November 9, 1956, and tunnel driving started 9,986 ft. in from the east portal at Grant on February 19, 1957. The access shaft was completed on September 30, 1957, three days less than a year after it started.

This shaft sinking was an enormous project itself, although it was designed only to facilitate tunnel work and will be of little or no value to the finished waterway.

The circular, concrete-lined shaft is 16 ft. in diameter and 916 ft. deep; it required a major job of drilling, blasting, mucking. A drill jumbo with four drills and jibs was used in drilling the blast holes. A crane was employed for hoisting until the permanent headframe and hoists were installed. An orange-peel bucket was used in muck-

ing, for it proved more effective than a clamshell. A battleship-type slip form was used for concreting and it did not have to be removed from the shaft between cycles. The shaft was started high up on the Continental Divide at an altitude of nearly 10,000 ft., near the old mining camp called Montezuma. This was about the only place an access shaft could be located to advantage. It was not needed farther west, for that part of the tunnel—an 8.5-mile section—could be driven from the west portal.

Just to the east of the shaft, the terrain becomes too rugged for a shaft. Here, the Divide climbs sharply upward and not far east of there is the summit of Landslide.

With the shaft completed and equipped with hoist, skip, man cages, and underground station, tunnel driving started eastward and westward from the foot of the shaft toward the east portal on October 1, 1957, and toward the west portal four days later. Now the tunnel was being driven from four headings, and, of course, advancing the bore through the Rockies was the main thing on this job.

Project Manager Adams said: "A rate of advance estimate is the controlling factor in all tunnel contracts and is determined both by condition and size of the tunnel. Size controls the number of drills that can be used and this in turn controls the drilling time as well as the type of loading and hauling equipment that can be used."

However, he added that advancement of the bore is not everything. "Footage is not the criterion for driving a tunnel," he said. "If overbreak is neglected in getting footage, it is quite possible to lose whatever advantage may be obtained on driving a tunnel by having to concrete the excess overbreak. Overall efficiency is the primary consideration."

Mr. Adams, his associates, and the crews of skilled workmen, with the aid of the Water Board's consulting engineers, did a great job of overall efficiency, and an important part of this was the blasting. Every inch of the tunnel was drilled and blasted, although some of the earth was too rotten for fast work. There were three major elements of prime importance in the blasting:

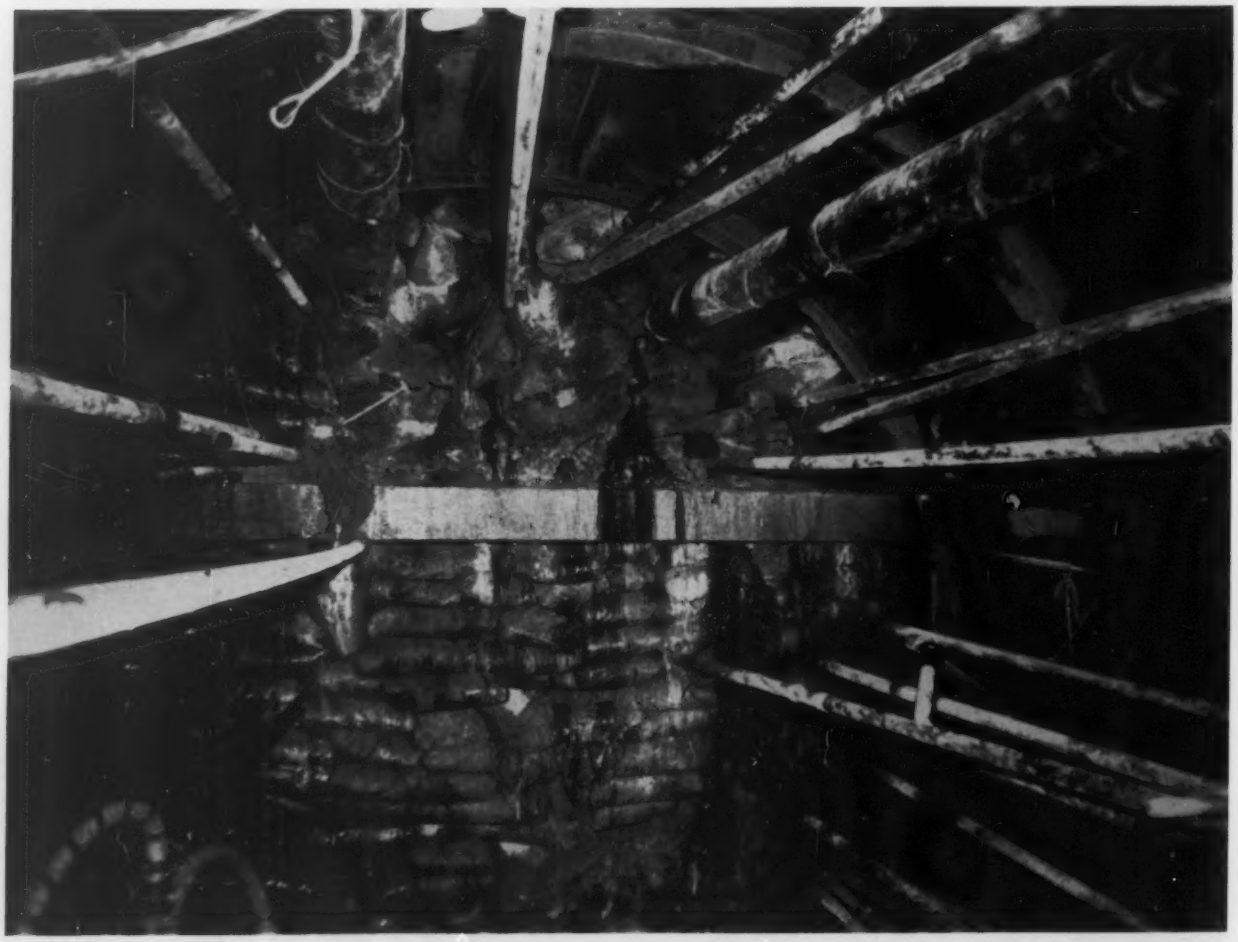
First, advance the hole.

Second, keep the correct shape and size.

Third, prevent overbreak.

New Section Heading

Drilling and blasting were essentially the same at all four headings, varying with the type and condition of



SANDBAG BULKHEAD: Driving from the west portal slowed to a crawl when a high-pressure flow was encountered. Sandbagging and bulkheading were necessary to halt the water flow.

material being blasted. Jumbos, which ran on the rail haulage track, pushed into place by battery-powered locomotives, or motors, were made in the shop at headquarters. Each jumbo had four drills and two hydraulic booms for position drilling. Ingersoll-Rand BD 35 (3½-in. drifters) were used. Ingersoll-Rand and Timken carbide insert bits were effective; bit sizes were 1¾, 1⅝, and even as small as 1½ in. New bits were used as starters; those reduced in size by sharpening as finishers. A bit was good for about 200 ft.

Straight carbon hollow 1¼-in. drill steel was used. Blue River bought raw steel and made it up in the steel shop at the west portal. The steel was cut into various lengths, usually 4, 5, 7, 9, and 11 ft.; it was then shanked and threaded.

Holes ranging from 9 to 11 ft. deep were started with 4- or 5-ft. steel, and only one change of steel was necessary. Drills were operated by air from the compressor stations located on the surface. Water sprayed through the steel and bits because wet drilling is required by law in Colorado.

The depth and pattern of the holes were determined by the type of material being blasted. Nearly every round was different. In some of the bad earth the holes were only 3 ft. deep. As a rule, the holes were from 7 to 11 ft. deep.

From 35 to 50 holes were drilled to the round. Blue River found that the pyramid cut was flexible and worked well in the various sorts of ground; therefore, this pattern was used in practically all the blast-hole drilling.

Four cut holes were drilled in the center, with four relievers just outside the cut. Generally speaking, the idea of the pyramid, as used by Blue River, is to blow out the center plug so that all the other holes slab to it. This means the main force of the blast is to the center, and this is an effective way of controlling size of bore and the shape, and in preventing overbreak.

The holes were loaded on the ratio of 4½ to 5 lb. of explosives to the cu. yd. of material in the solid. In some places the ratio was 7 lb. of explosives, and in shales the loading was as low as 2 lb. of explosives per cu. yd. of material in the solid.

With the jumbo as a platform, the holes were loaded with Gelamite®, a semigelatin type of explosive, or its equivalent. This powder is about 45% strength. The primer, a cartridge 1¼ by 8 in., was placed in the bottom of the hole and equipped with an electric delay cap. Delays ranged from periods 1 to 10 and were arranged so the slabbing was to the center. After the primer came another cartridge of Gelamite, which was tamped. At times, 16-in. cartridges were used to speed up loading. The hole was loaded with explosives, which were tamped to within 18 in. of the collar. No stemming was used.

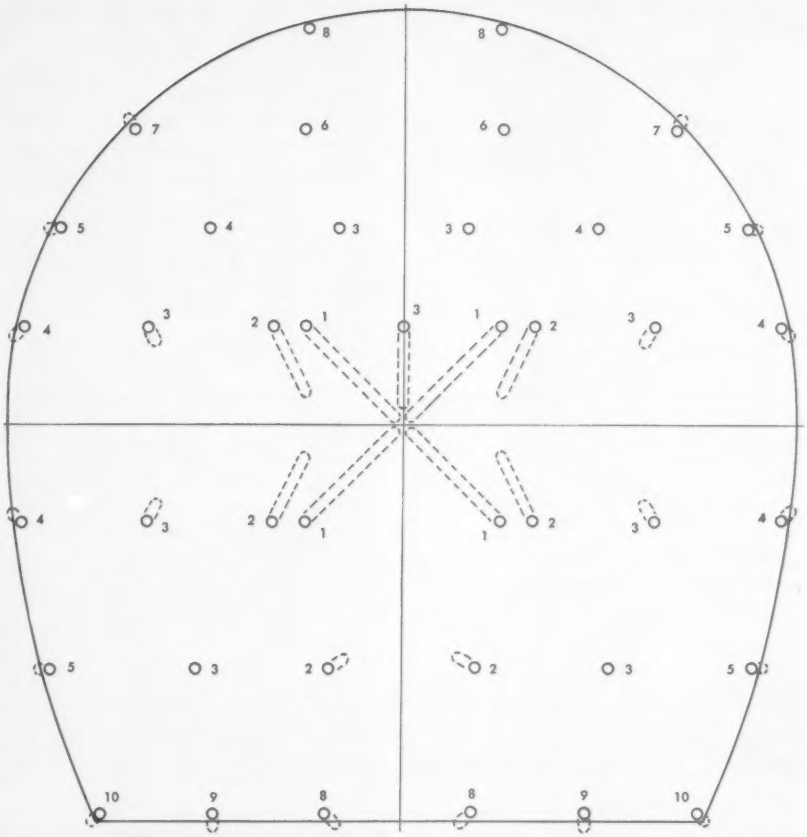
The round was hooked up in parallel with 16-gauge naked copper wire, to which the leads were tied in. To guard against accidental or premature contact at the switch, the hookup was completed as the workmen retreated from the face. The round was detonated from a 220-volt power line. The firing switch was located at a safe point about 1,000 ft. from the heading.

The pattern of hole placing and loading achieved satisfactory results and no significant secondary blasting was necessary.

The explosives used had low density, water resistance, and cohesiveness, and detonated with a uniform velocity which provided effective control. Fumes were no problem.

Mr. Adams said that this system, with heavy loading and no stemming, was perhaps not the most efficient way to use explosives, but that speed was the essence of the rather complicated cycle. For example, the delay of a minute or so in loading a round or in moving the equipment in the naturally cramped quarters of a tunnel could add up to a considerable amount of time in the course of a week; it could amount to something of economic importance, and affect the time-table, in the course of a few months or a year.

The cycle—drill, shoot, muck, put



TYPICAL DRILL ROUND: Drilling and blasting techniques varied to meet the conditions of the material as the tunnel progressed. A typical round consisted of 41 holes, using the pyramid cut. Numerals indicate the order of firing.

(Drawing, courtesy Blue River Constructors)

in necessary supports, move the utilities (ventilation, haulage track, water, power) forward, and then repeat—started with the drilling. The jumbo nosed forward, and the drills screamed. After loading with explosives, the drilling equipment was moved to a safe distance for the shooting, and there could be no more drilling until the mucking was accomplished.

Mucking

After the round was fired, an Eimco 40 mucking machine, the overshot type, moved in and started loading the blasted material into 5-cu. yd. Card-built Granby-type mining cars. Short sections of track were laid to advance the air-powered mucker; these were later replaced with standard lengths of rail. A California switch—a double track that slides on the main single-line track—was used, making it possible to shunt empty cars to the heading and remove loaded cars. On the average, a 7-ft. round produced about 80 cu. yd., or 16 carloads, of loose muck. On such a round, the mucking usually required about 1½ hours.

When mucking was completed, necessary supports were placed in line and grade. Installation of utilities was carried on behind the heading, and sidings were laid at intervals to store equipment and supply cars, during the course of a normal cycle.

With cleanup accomplished, the mucker was brought out and the jumbo eased into position to start another cycle.

Compressed air was available through an 8-in. line from the compressor stations, and about 2,700 cu. ft. of air was required at each heading. Water was supplied through a 4-in. line under 80-lb. pressure. A three-conductor cable, carrying 4,160 volts with needed transformers for the power and lighting circuits, transmitted the electric power. Unexpected power demands could be handled instantly.

As in all long tunnels, ventilation was a problem, especially when a heading had advanced up to nearly 10 miles, as the east portal did. For each heading a high-pressure fan of 10,000 cu. ft. per minute forced outside fresh air into the working area through a 26-in. pipe. This ventilation system also cleared the heading of fumes and dust after blasting. A few minutes before a round was fired, the blower was reversed, or turned on "suck," as the men say, and exhausted air from the heading. This permitted the men to complete the new cycle without delay. Advancing the ventilation system was quite a job: it came in 40-ft. lengths, each weighing more than 1,000 lb. Two hydraulic-jack jumbos on a flat car lifted the pipe into place in the ceiling until it was anchored.

Pumping equipment was also installed and hooked up at regular intervals as the heading advanced.

In the portal headings, blasted material was hauled outside in the rail cars; the 36-hp. locomotives usually pulled 10 cars on the uphill through the west portal and as many as 18 downhill through the east portal. The rail line was equipped with block sig-

TYPICAL ROCK SECTION: Formations encountered in driving the Roberts Tunnel included quartz monzonite, decomposed pre-Cambrian gneisses, Dakota sandstone, Niobra limestone, unbaked Pierre shale, and baked shales.

SUPPORT: In the bad rock sections, totaling about 15 miles, steel supports were necessary. In this section of the west portal, steel rib supports were placed on 18-in. spacing.

nal system operated by pull switches. Cars were dumped in the waste area over a camelback ramp.

Blasted material in the shaft headings was hauled to the shaft and dumped in pockets. It was hoisted out in a 5-yd. skip made by C. S. Card Iron Works, which also manufactured the 70-man-capacity cage. The skip dumped into a bin from which 18-yd. Euclid trucks, equipped with end-dump beds, hauled to the waste dump.

With the work tuned acutely to overall efficiency, advancement was rapid in good, hard material, but down there in the complex bowels of the peaks all the material was not good and hard. Blue River Constructors ran into all sorts of trouble with earth and water. Not only did these factors slow the driving cycle, but they necessitated the installation of a great deal more steel and other supports than was expected and also led to a tremendous amount of grouting and pumping.

Geology

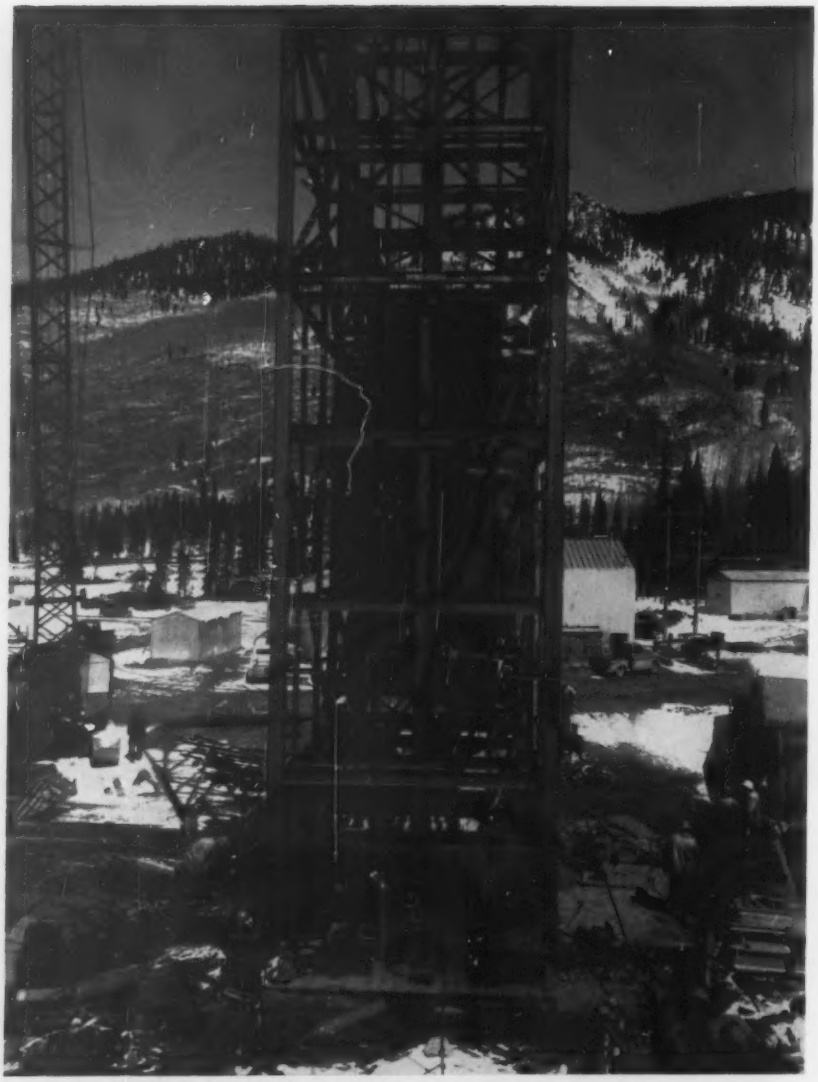
The tunnel passes through some of the more complicated geology of the Continental Divide, including various sedimentary, metamorphic, and igneous rocks. There are numerous fault systems, some of them in mineralized zones. Formations include quartz monzonite (coarse-grained granite type), Idaho Springs Formation (decomposed pre-Cambrian gneisses), Dakota sandstone, Niobra limestone, unbaked Pierre shale, baked shales. This is mining country, but little ore had ever been sought at the depth of the tunnel; therefore, it was exciting to explore in unknown depths. No metals or minerals of significance were encountered.

Manager Adams is a strong advocate of exhaustive geological studies for tunnel work. "More contractors have gone broke in the tunnel business than in any other phase of contracting," he said. "Geology is important from the standpoint of both the owner of the tunnel and the contractor. The question of picking the tunnel alignment in the first place is important to the owner. To the contractors bidding the work, a better knowledge of ground conditions leads to more accurate bidding."

Despite the ruggedness of the terrain of the surface, extensive geological work had been done on the Roberts Tunnel. Conclusions had been based mainly on outcrops. In sections between the west portal and the shaft there was not enough outcrop to determine the geology, and the Water Board had seven diamond drill holes put down for a study of conditions.

Water Trouble

It was known that near the west portal a Williams Range thrust fault with a displacement of several miles cut the tunnel route twice, resulting in highly fractured conditions. This caused major bad-earth and water problems. In the spring of 1959, a troublesome situation developed in the heading being driven from the shaft toward the west portal. Water poured in under high pressure through feeler holes and tunnel driving had to be suspended in that heading for seven



ACCESS SHAFT: Because of the length of the tunnel, more than 23 miles, a shaft was sunk so that the tunnel could be driven from four headings. The concrete-lined shaft is 16 ft. in diameter and 916 ft. deep.

weeks. Only 600 ft. above the tunnel and 500 ft. away from it horizontally the Snake River was flowing, and this was probably the source of most of the water. The ground was very rotten.

Grout pumped under pressure of 1,500 p.s.i. through a series of feeler holes failed to stop the water. At last, 200-ft. holes were bored with diamond drills and grout was pressured in until the water was checked; however, tunnel driving was slow in this bad ground and bulkheads and feeler holes were necessary. Short rounds—usually about 3 ft.—were drilled in this section of the tunnel.

The heading driving from the west portal also hit almost oceans of water, and extreme high-pressure flow was encountered approximately halfway between the east portal and the shaft. Here, sandbagging and bulkheading were necessary, and the operation was slowed to a crawl.

But wherever water and bad, squeezy earth were encountered, Blue River met the problem and kept advancing the tunnel. In some wet spots, holes were drilled 35 to 40 ft. in the heading and pipes were installed. Then grout was pumped through the pipes to control the water. In some of the worst places, lengths of rail steel spiling were jammed in as support.

Tunnel Supports

About three-fourths of the tunnel, or more than 15 miles, had to have supports, and in some of the good rock sections roof bolts were used.

Main supports are steel ribs, usually 6-in., H-shaped, 20-lb.-per-ft. arch rib assembly; this has two ribs to a section and each side is 16 ft. long. Spacing depended on the ground, but the maximum was 5-ft. centers. However, it wasn't unusual to space them closer than that and often skintight. In some places, 8-in. steel, weighing 31 lb. to the ft., was used. In exceptionally bad ground, steel struts were laid across the bottom to keep the lower end of the ribs from being sprung together.

Steel—the wedges and lagging—was backed with Oregon fir of 25% construction grade. A sawmill was maintained to prepare the timber.

Supports were placed from the drill jumbo as a platform as the tunnel advanced, and this became a part of the cycle except in the rock sections.

While tunnel driving, with all its woes, was progressing, two other tremendous jobs of excavation were under way. One of these was the emergency gate shaft some 450 ft. downstream from the west portal. It has a finished diameter of 16 ft. and is 208 ft. deep. This installation did not facilitate the driving of the tunnel; it will provide for operating equipment to regulate the flow of water through the completed tunnel, and other necessary controls.

The other excavation was that of sinking the surge chamber 924 ft. upstream from the east portal. It is 380 ft. deep. Except for the bottom 42 ft. of the chamber, which is 10 ft. 3 in. in diameter, this shaft is 20 ft. 6 in. in diameter.

The emergency gate shaft and the surge chamber were drilled, blasted, and mucked much in the same way the access shaft was sunk. Future plans call for a 6,000-kw. hydroelectric power plant at the Grant end; this will be done when diversions from the

Blue River are of sufficient volume to make such a generating plant economically feasible. It is reckoned to come in about 1975.

Outlet facilities at the east portal, that is, the flow of water from tunnel to river channel, will be installed under a separate contract.

Concrete Lining

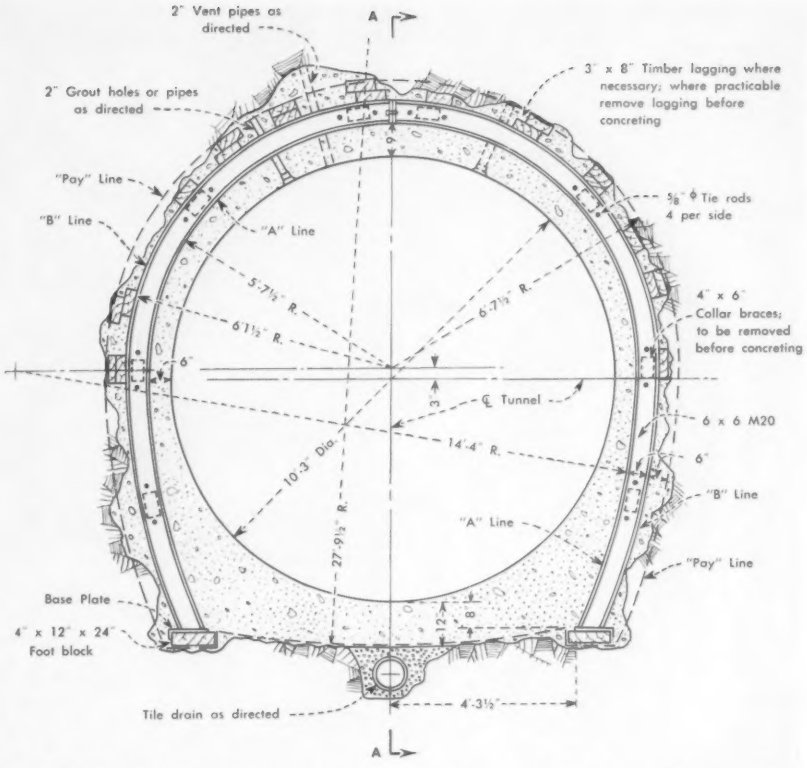
Looking toward another major phase of the job, Blue River Constructors started aggregate production well in advance of the final holing-through. A gravel pit was developed 3 miles west of headquarters offices. About 305,000 tons of gravel was stockpiled at the west portal and 275,000 tons near the east portal. At least 100,000 tons of sand was stockpiled at each location.

As soon as the tunnel was holed through, the cleanup and preparation for concrete lining started. In the cleanup, Eimco 630 mucking machines and dozers were being used. The muckers load on a traveling conveyor whose belt discharges into the muck cars. Some of the preparation included the removal and replacement of distorted sections of steel supports. After the tunnel was finished, ventilation was no longer a problem; fresh air usually "stacks" up the shaft, causing breezes from one end of the bore to the other.

The lining will have a minimum thickness of 8 in. all the way around, with about 5 yd. of concrete being used to the lin. ft.

Lining work started at about midpoint of the tunnel and is progressing in each direction. Sand, gravel, and cement are being dry-batched at the two portals and hauled in aggregate cars that replaced the muck haulers. The concrete is mixed near the point of use and pumped into the forms. Three conveyors handle the material. Cars bottom-dump on a conveyor which discharges into a hopper; a second conveyor elevates to the mixer and the third moves the concrete to the top of the pump.

The lining is being poured in two sections, bottom and top, the length of



CROSS SECTION: The unlined tunnel is horseshoe shaped and 12 ft. 6 in. in diameter. When lined with concrete, the waterway will have a finished diameter of 10 ft. 3 in. Most sections of the tunnel required steel rib supports.

(Drawing, courtesy Denver Board of Water Commissioners)

MUCKING: After the round was fired, an Eimco 40 mucking machine moved in and loaded the blasted material into Granby-type mine cars.

HOLING-THROUGH: Climaxing days of meeting and conquering difficulties was dramatic holing-through which connected the tunnel from the west portal with the head driven from the access shaft.

the tunnel. A great deal of grouting will be necessary to wind up the job.

When the lining is completed and all equipment removed, the tunnel will be completed. The access shaft will be of no particular use, but it will be capped and left intact. A small battery-powered car, which will be lowered and raised in the emergency gate shaft, will be used for periodic inspection of the tunnel after it is in use.

This job, and especially the excavation phase, required many good-sized installations. The main warehouse for the overall project is at Arvada, just outside Denver; equipment and supplies are received there and trucked to location. Northwest 25 cranes are used for loading and unloading heavy materials. Three repair shops—one at each portal and the third at the shaft—and three machine shops were installed. Compressor stations are located on the surface at the portals and shaft. Ingersoll-Rand, Twin Sullivan, Chicago Pneumatic, and Gardner-Denver compressors are used.

Caterpillar No. 12's with blade are used to control snow and maintain roads; these are six-wheeled, rubber-tired machines. Caterpillar D-8 dozers kept the waste dumps in order.

Power is supplied by Public Service of Colorado at the west portal and the shaft, and by REA at the east portal. Good roads lead to both portals and the shaft.

During the excavation phase, around 600 men were on the job underground and on top. During the lining operation, an average of about 450 men is needed.

Safe Operations

Despite the bad earth, water, and other hazards during excavation, an excellent safety record was maintained; there were no fatalities and very few serious injuries. Radio and telephone communication was maintained, and still is, between all stations. George (Sonny) Hallen is the full-time safety engineer, having replaced Wesley Fink, who was promoted to superintendent in June, 1959; his office at headquarters is a fully equipped first-aid station; his car is equipped with stretchers, blankets, gas masks, respirator. Aside from traces of methane in some places, no gas of significance was encountered. Ambulances are maintained at all entrances and first-aid kits and other safety equipment in all working areas. Blue River Constructors brought in a physician and set up a clinic to take care of workmen and families.

Labor relations have been excellent. The visitor detects a sort of *esprit de corps* among the workmen. This younger generation of "tunnel stiffs" lay little store by some of the old superstitions of the trade, such as refusal to enter a tunnel after a woman has been in it, but, like old-timers, these modern, machine-age hard-rock miners are usually softhearted human beings.

One night a stray dog, a part-collie female, showed up at headquarters. The men figured that someone had

dumped her. She looked to have been mistreated; one eye was badly injured. The men adopted the shivering pooch and named her Molly. She was given a bed in the electrical department. Men started carrying in bones and other food and Molly waxed fat. She had a friendly and appreciative wag for every man. Molly was usually around the electrician's quarters, but isolation in a tunnel camp did not keep her from leading a dog's life.

Shortly before the tunnel was holed through, Molly gave birth to five husky pups. The men worked up a scheme whereby each would draw for a chance to pay $3 for a pup; the money was spent in taking Molly to Denver to have her eye fixed.

Three years ago, someone deserted a brindle pussy cat at the east portal office at Grant. She was quickly adopted and named Genevieve. At the time, mice and some rats were trying to invade the place. Genevieve took care of that. She invariably shows up at lunch time and has little trouble persuading the men to count her in. Like Molly at Dillon, Genevieve hasn't devoted full time to Blue River Constructors. In her time there, she "found" three litters of kittens. The men had difficulty finding homes for the last furry bunch and Genevieve had an operation, restricting her activities to that of contented mouser.

Key Personnel

In addition to L. H. Durst, who is in general charge of operations for the sponsoring partner, and Mr. Adams, the project manager, members of the staff include David Morse, assistant project manager; David Pearson, superintendent of the shaft; Emery Gardner, superintendent at the west portal; Bob Silva, superintendent at the east portal; Tom Holley, chief engineer; Ray Wilson, office manager; Robert Penn, electrical engineer; Henry Eckes, master mechanic.

The Water Board's consulting engineering firm, Tipton and Kalmbach, Inc., of Denver, has kept a staff of engineering personnel, including a consulting geologist, on the job to supervise construction. H. J. Dickinson has been the construction engineer for Tipton and Kalmbach.

The Water Board still has a lot to do, one of the principal chores being the completion of the reservoir. And the Board must also do something about the scenic old town of Dillon. When the lake is full, the present Dillon will be under mountain water. The Board has set aside land about 2½ miles from Dillon for a new townsite.

It has taken a long time and a lot of doing, but the realization of Denver's long dream for plenty of water from the western slope of the sky-high Continental Divide is close at hand. Men who can conquer frowning mountains have brought it about.

Harold D. Roberts, for whom the tunnel was named, will never see this. He was one of the early leaders who visualized the tunnel and worked for it; he died shortly after tunnel construction started.

STOCKPILE: A gravel pit developed near headquarters produced aggregate for lining the tunnel. Stockpiles were maintained at each portal.

Aged Ore Knob Mine Reopened By Nipissing Mines

Copper mine in North Carolina, inactive since 1883, once employed 500 men

J. R. DANIEL*

HIGHER copper prices have brought new life to an old property that once was one of the largest copper mines in the United States. Back in 1883, the Ore Knob Mine, Jefferson, North Carolina, was a thriving producer employing up to 500 men. Declining copper prices in 1883, however, forced the closing of the operation, and it had remained inactive until recently. The deposit, discovered in 1855, was opened up by S. S. and J. E. Clayton of Baltimore in 1873. In the next ten years the mine produced 25,000,000 lb. of copper from 200,000 tons of ore before it was closed down.

*Hercules Powder Company
Birmingham, Alabama

The United States Bureau of Mines drilled the abandoned property in 1942-43, putting down 20 diamond-drill holes for a total of 4,945 ft. While this drilling disclosed that there was still copper in the mine, nothing was done with it for another ten years until the Nipissing Mines Company, Ltd., of Toronto, Canada, leased it from the owner, R. G. Lassiter.

Core drilling, begun in 1953, put down 31 holes for a total of 23,646 ft. and indicated over 1,000,000 tons of ore. Shaft sinking was begun in 1955 by Cowin & Company, Inc., of Birmingham, and completed in July, 1956. With the sinking of the shaft, the mine was developed underground, the plant installed, and production started in March, 1957, by Appalachian Sulphides, Inc., a wholly owned subsidiary of Nipissing Mines.

The Ore Knob Mine is situated 11 miles east of Jefferson, and 1 mile

SURFACE BUILDINGS: Equipment on the surface, showing the hoist and mill and crusher buildings.

north of the North Carolina State Highway 88 in the Appalachian Mountains 2 miles west of the Blue Ridge. The shaft collar stands at an elevation of 3,040 ft.

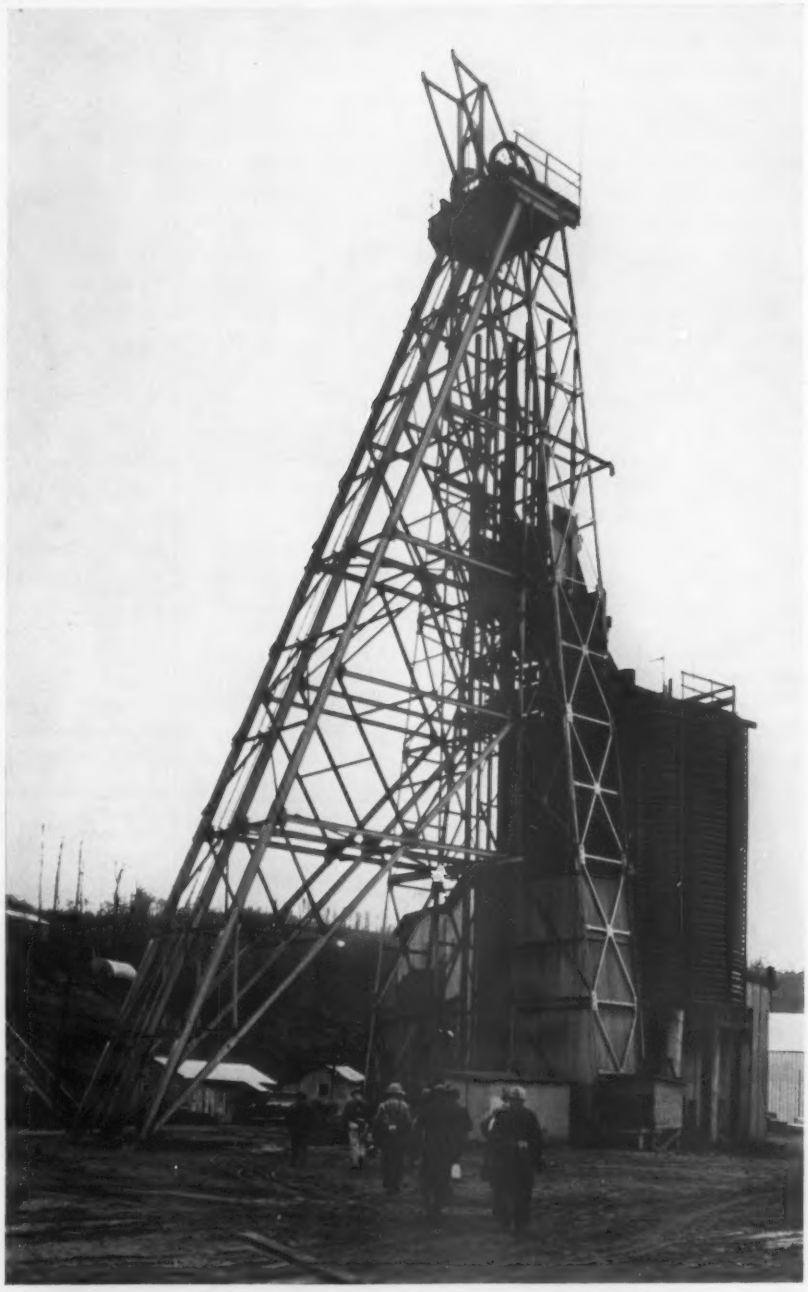
The Blue Ridge Electric Membership Corporation supplies power to the mine at 2,300 volts through a 2,000-KVA substation. Concentrates are trucked 13 miles to the Norfolk & Western Railway siding at Smethport, North Carolina. Employes have been recruited from the surrounding countryside, some men driving as much as 80 miles to work. Six houses for staff members only are located at the mine.

The vertical shaft has been sunk to a depth of 1,286 ft. with working levels at 560 ft., 700 ft., 840 ft., 980 ft., and 1,120 ft. Drifts develop the vein for 1,300 ft. east and 1,200 ft. west of the shaft.

24,000 Tons of Ore Monthly

The mine is currently producing 24,000 tons of ore monthly, equivalent to 900,000 lb. of copper. Initial production was 12,000 tons of ore each month, which was doubled in 1959 with the improved copper prices.

The rock is a quartz-mica gneiss, similar to a granite gneiss, very hard, and because it forms slabs in many places, much rock bolting must be done. The ore is a combination of heavy sulphides, chalcopyrite, pyrrhotite, and pyrite in a vein varying from a few inches to 55 ft. in width. This vein averages 35% sulphides.



HOIST: View of the headframe, showing miners going to work.

Equipment Used

Appalachian Sulphides uses Atlas Copco Airleg drills exclusively for drifting and breasting in shrinkage stopes. Model BBC-22W drills on BMP-31 bench drill mountings are used for benching in open stopes where the vein is over 20 ft. wide. Model BBD-46WS stopers are used in raises.

With these drills, Appalachian uses Sandvik Coromant drill steels, ⅞ in. hex. with 4¼-in. shank and integral tungsten carbide chisel bits. Starters have 1⅝-in. bits. In raises, it uses Sandvik Coromant tapered socket detachable tungsten carbide bits; on the benches, ⅞-in. extension steel with 1⅝-in. threaded tungsten carbide bits. With this equipment the average drilling speed is about 20 in. a minute. On the surface two Atlas Copco AR-7 compressors, 1,800 c.f.m., drive the drills and Eimco Model 21 loaders.

Drill Patterns

In raising, drifting, and stoping, typical drill patterns make use of 1¾-in. holes. In raising, 24 to 28 holes 6 ft. deep are drilled. In a 5 by 5-ft. raise the company uses a 6 to 9-hole burn cut. An 8 by 8-ft. drift makes use of 32 holes 1¾ in. in diameter and 6 ft. deep, or 36 holes with a 6 to 9-hole burn cut. Three holes in the burn are drilled 2 in. in diameter. All of these are loaded with 1 by 8-in. Gelamite®

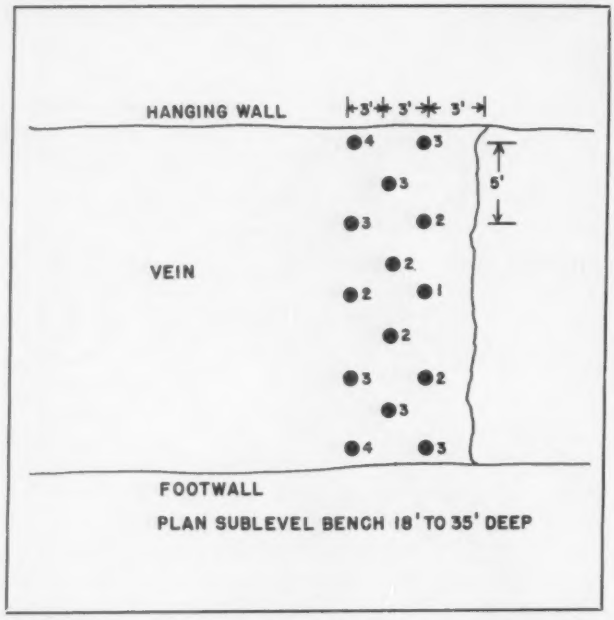


FIGURE 1: For blasting a sublevel bench 18 to 35 ft. deep, holes 1⅝ in. in diameter are drilled on 5-ft. spacings with rows of holes 3 ft. apart. A 45% strength semigelatin, packed in 1¼ by 16-in. cartridges, is used. The rotation of firing is shown by the numerals alongside the drill holes.

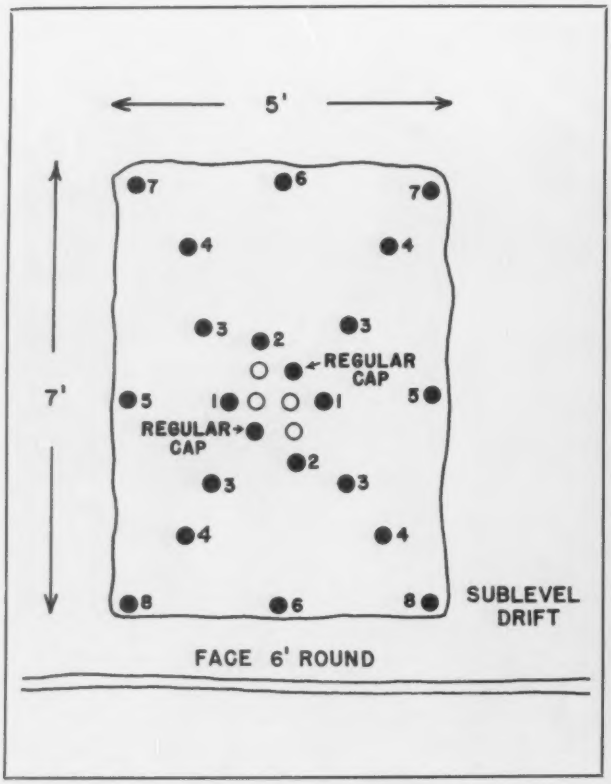


FIGURE 2: A sublevel drift drill pattern included six burn cut holes. Four of these are unloaded, while two located at opposite corners of the burn cut are loaded and primed with instantaneous caps. Numerals indicate order of firing.

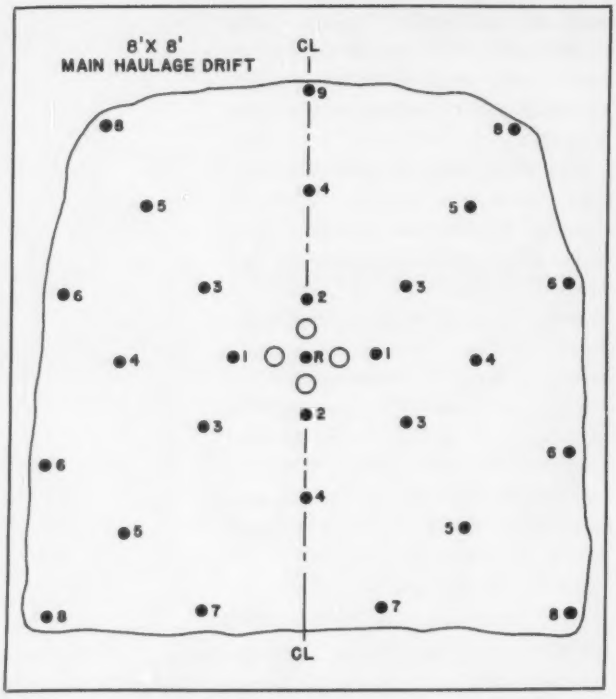


FIGURE 3: Typical drilling pattern used in a main haulage drift includes five burn cut holes with the center hole primed with an instantaneous blasting cap. The other four holes are not loaded. The remainder of the loaded holes in the round were detonated with regular No Vent delay blasting caps ranging from periods 1 to 9 as indicated by the numerals in the diagram. The average yield is 28 tons of broken material per round in an 8 by 8-ft. drift.

DRILLING: Atlas Copco Airleg drills are used for drifting and breasting in shrinkage stopes.

2-X, and primed with regular No Vent® Delay Caps. For stoping, 8 to 10-ft. holes 1¼ in. in diameter are drilled at the bottom of the stope and loaded with 1 by 8-in. Gelamite 2-X and primed with regular delay caps for breasting. Some millisecond delay caps are used for slashing.

For benching up to 35 ft. in height, 1⅝-in.-diameter holes are used and 1¼ by 16-in. semigelatin, 45% bulk strength, is loaded. All blasting is done from a master switch on the surface, with isolating switches on each shaft station.

Powder Factor

With this blasting plan, the powder factor is as follows: benching, 1.48 lb. to the cu. yd.; shrinkage, 2.81 lb. per cu. yd.; secondary, 0.59 lb. per cu. yd.; in 8 by 8-ft. drifting, 16.0 lb. to the ft. advance; 5 by 5-ft. raising, 9.5 lb. per ft. advance. No stemming or tamping is used.

Regular and millisecond delay caps are the detonators employed, normally in series, occasionally in parallel. All blasts in the mine are connected in parallel to the main blasting line and fired from the surface.

Secondary blasting is done in draw holes, and on the main ore pass grizzly by blockholing using either electric caps or No. 6 caps and tape fuse. The ore is mucked by Eimco loaders in draw holes, trammed to an ore pass, hoisted in 4-ton bottom-dump skips, crushed on the surface, and milled.

The equipment for the mine consists of two Atlas Copco AR-7 compressors; the hoist is a Nordberg double drum, 6½ ft. by 42 in., rope speed 900 ft. a minute and diameter 1⅛ in. Power is supplied by a 300-hp. Westinghouse motor. Power for the rock drills and loaders is supplied by eight Mancha Little Trammer 1½-ton motors, and one Mancha Titan 2½-ton motor.

Mill Equipment

The copper ore mined is concentrated in a flotation mill having a capacity of 950 tons daily, and the concentrates shipped to a custom smelter. The ore averages 2% copper, the concentrates 28% with a 93% recovery.

The mill is equipped with a Rogers 21 by 36-in. 75-hp. crusher, and a Symons short head 4 ft. 150 hp.; two 200-hp. Denver ball mills 7 by 7½ ft.; two Akins Type S 54-in. classifiers; 40 No. 48 and 16 No. 36 Agitair flotation cells; and Eimco Agidisc 6-ft.-diameter 4-disc filter.

Safety is the responsibility of the mine shift bosses and other immediate foremen. A safety contest is carried on among the various shifts, with cash awards to the bosses and prizes to the men with accident-free records. Safety regulations are strict, with penalties up to and including discharge for infractions.

Philip Eckman is mine manager, F. A. Nabb is mine superintendent, and R. H. Quesnel is mine captain. Chief engineer and geologist is W. J. Daffron; D. J. Hathaway, mine geologist; S. J. Nameth, mill superintendent; N. J. Myers, chief electrician; C. L. Crouse, master mechanic; L. V. Sheets, surface foreman; and E. L. Tommey, accountant.

TAMPING: Miners loading and tamping dynamite into a drill hole in a stope bench.

LOADING: The ore is mucked by Eimco 21 loaders and trammed to an ore pass.

Controlled Blasting Solves Difficult Problem

A delicate blasting job was successfully completed without disrupting factory routine when small dynamite charges were used to remove concrete loading platform

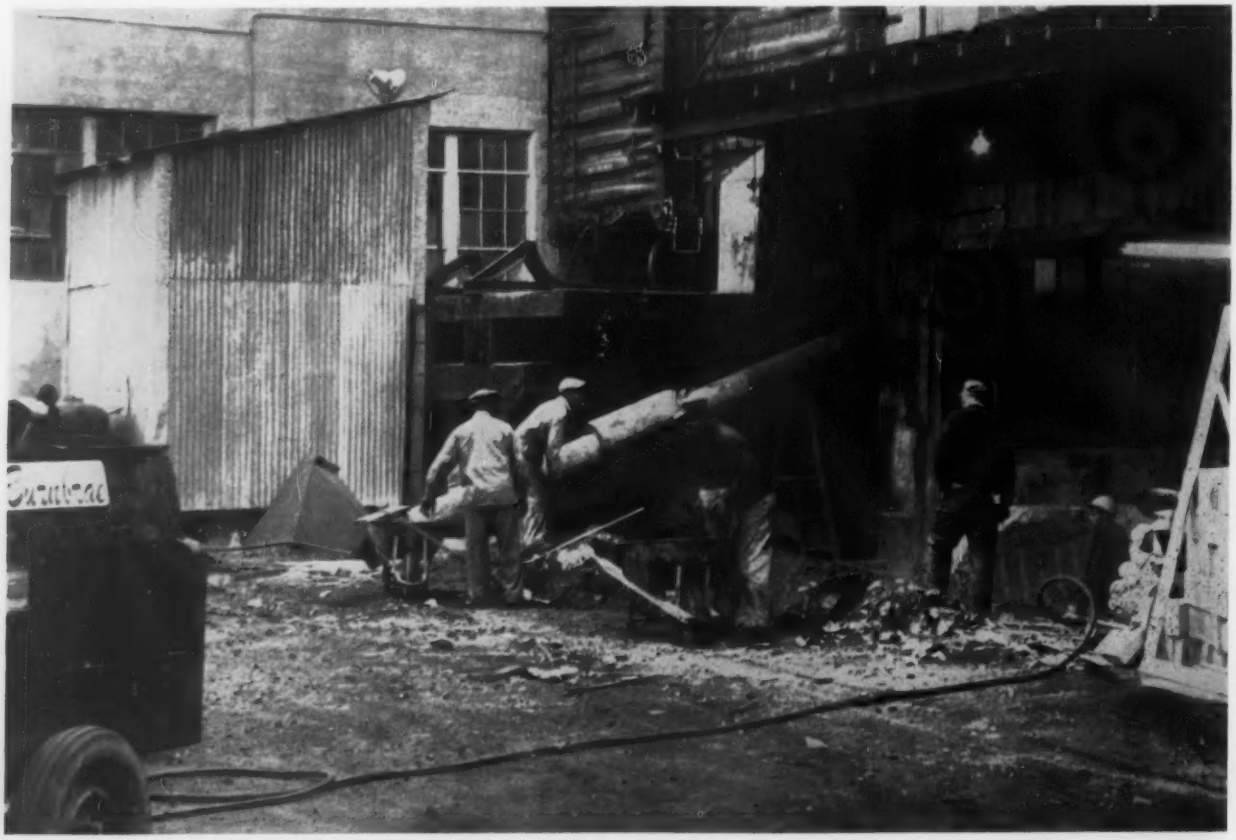
WILLIAM F. HALLSTEAD*

DYNAMITING in a small room, closed on three sides, is tough enough. Add a bank of windows along one wall, an overhead door raised so that 20 glass panes are directly above the blasting area, and orders not to interrupt mill operation—and you've got a difficult problem of blasting control on your hands.

*517 Wyngate Road
Lutherville, Maryland

Such was the situation faced by Burnbrae, Inc., a Baltimore blasting company. The case in point was the removal of a loading platform in the front of a machine shop annex in the DCA Industries, Inc., food-packaging factory near Ellicott City, Maryland.

The concrete platform consisted of a 5 by 16-ft. slab laid across two end walls, each 16 ft. in length, 4 ft. high, and about 11 in. thick. The object was to replace the platform with a hydraulically operated freight elevator.



CLOSE QUARTERS: An overall view of the blasting area shows the difficulties encountered by the demolition crew in removing a concrete loading platform. At this point in the operation, the platform and front support have been removed.

FRONT VIEW: The confined work area pictured above necessitated extreme care in all phases of the blasting operation. ↑

SMALL CHARGES: Closeness of electric fixtures and windowpanes directly overhead → stressed the need for small explosive charges.

A CONTROLLED BLAST: Fractional dynamite charges and the use of a heavy mat and iron sheets limited the amount of fly material. ↓

Limited Working Space

As is customary with these cramped concrete-removal operations, the work began with jackhammers. In this case, the chippers knocked apart the top slab with comparative ease. But when it came to the two supporting walls, the pneumatic hammers got nowhere, and the removal job was turned over to Burnbrae as subcontractor.

Using an air drill powered with a Davey compressor, Burnbrae's blasting crew drilled five holes vertically in the platform's front wall. Each hole was deck-loaded with one cartridge of 40% gelatin dynamite. The cartridges were cut into six to eight pieces, with dirt stemming separating the pieces. A length of Primacord* was affixed to the bottom piece of explosive and extended out the top of the bore hole. To this Primacord was taped an instantaneous electric blasting cap. Holes were fired individually from a position 60 ft. away with a twist-type blasting machine. (Continued next page.)

*Reg. U. S. Pat. Off. by The Ensign-Bickford Company

Following the demolition of the front wall, a rather large rock was discovered below ground level between the walls. Since the elevator's foundation would extend well below this rock, the dynamiting team broke up the rock with two 15-in.-deep bore holes, each loaded with one-half cartridge of 40% gelatin dynamite.

Precision Blasting

The crew now moved to the rear wall, where the work became more difficult from the control standpoint. About 15 ft. from this wall were a number of oil-storage drums and an array of sugar-transfer machinery. Beyond this was the sliding door into the machine shop proper where employes were working.

The rear wall was drilled with six 1½-in.-diameter vertical bore holes and loaded in the same manner as the five holes in the front wall. The toughest operation here was covering the blast. The tight working quarters precluded the utilization of any type of crane for placing blasting mats. The effort was largely a hand operation, with a degree of help from a Clark forklift borrowed from DCA.

The blasts were covered with one ¾-in. mesh blasting mat and three 4 by 5-ft. $\frac{3}{16}$-in.-thick iron sheets. The mat was placed first and the sheets were then laid on top. The system worked nicely, though it was tedious and hard work. Not a window was cracked, nor were any of the several exposed light bulbs and fluorescent fixtures damaged. What little fly occurred was directed away from the room's interior.

The hand placement of cover made the blasting work fairly slow in this instance. Nonetheless, it was completed in far less time than had already been spent in futile chipping. The walls were removed cleanly and without any damage to the connecting building. Once again, fractional dynamite charges had proved just as safe and far more efficient than a jackhammer for a specialized job.

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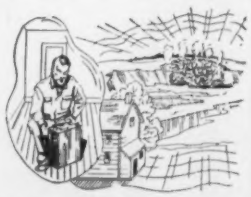

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Over 15 ft. per hr. through solid granite

with Stardrill-Keystone KF-50 rotary gun drill

This production — reported by B&R Diamond Drilling Co., of El Cajon, California — shows again why more Stardrill-Keystone rotary drills are sold for the tough jobs. On the KF-50 application pictured, operator used tricone rotary rock bit to drill down to solid rock, then switched to down-the-hole air hammer to sink 15 ft. per min. through solid blue granite. Water-cooled piston compressor lifted cuttings thru water from 300 ft.

Handles scattered mine, quarry work

Heavy duty in every respect, the KF-50 mounts a Cummins diesel engine, a 500 CFM two-stage compressor, a 158 gpm duplex piston mud pump, and has retractable rotary table. Variable-speed pull down, with infinite feed adjustment from 0 to 20 ft. per min., insures maximum permissible hole production in any type formation. Bit pressures to 30,000 lbs. are obtainable. Depending on your needs, mud pump can be omitted, with larger-capacity compressor available.

Get the complete story on the truck-mounted KF-50. You'll find it "has what it takes" to cut your costs on blast hole drilling, sampling, and exploratory work. Get in touch with your Stardrill-Keystone distributor, or write for complete specs.

Stardrill-Keystone offers a wide range of rotary, down-the-hole, and combination drills, tools and attachments for mining and quarry applications. Your Stardrill-Keystone representative is available to make specific recommendations for your particular problem without obligation.

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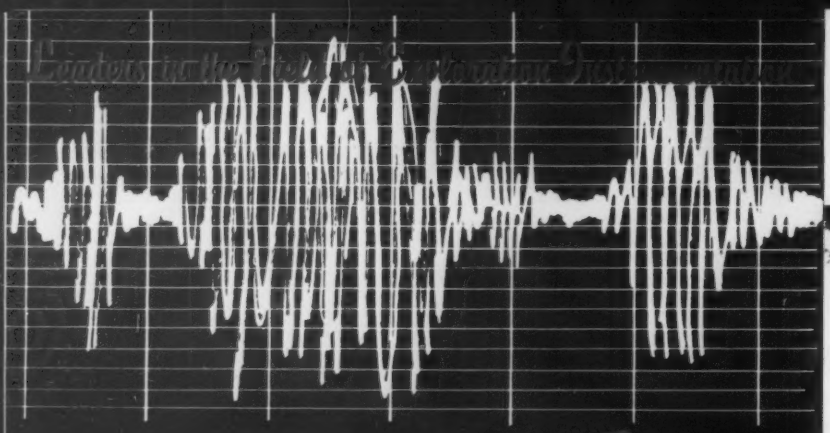

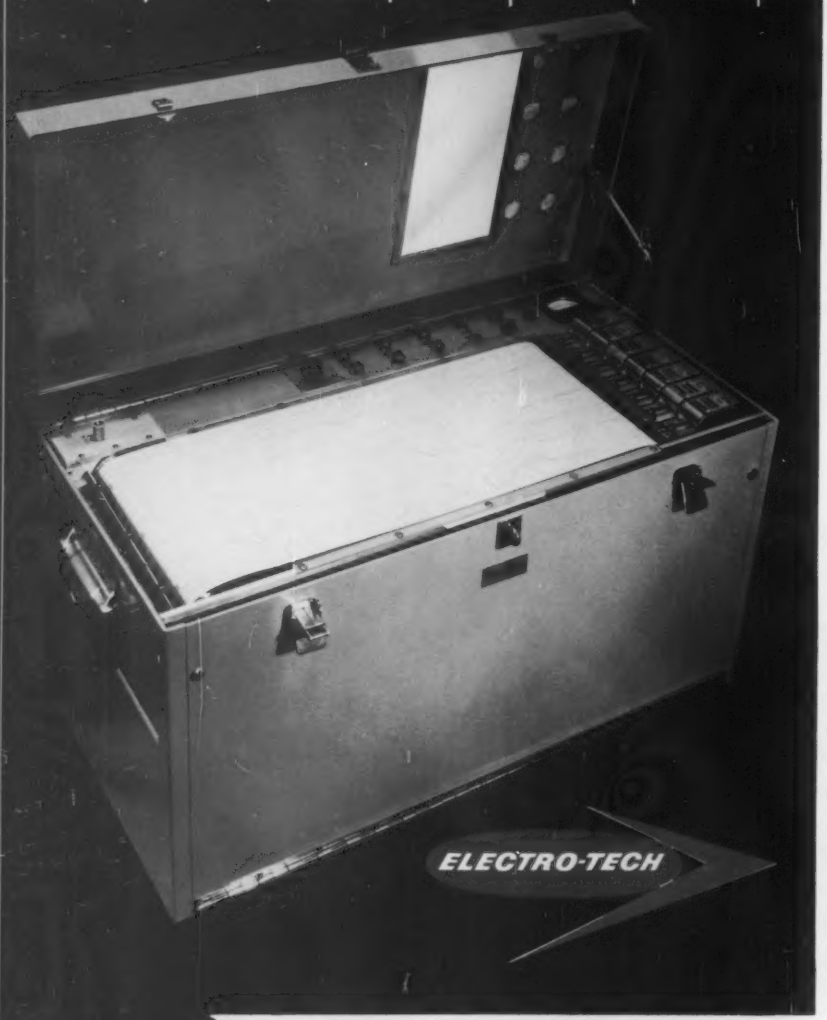

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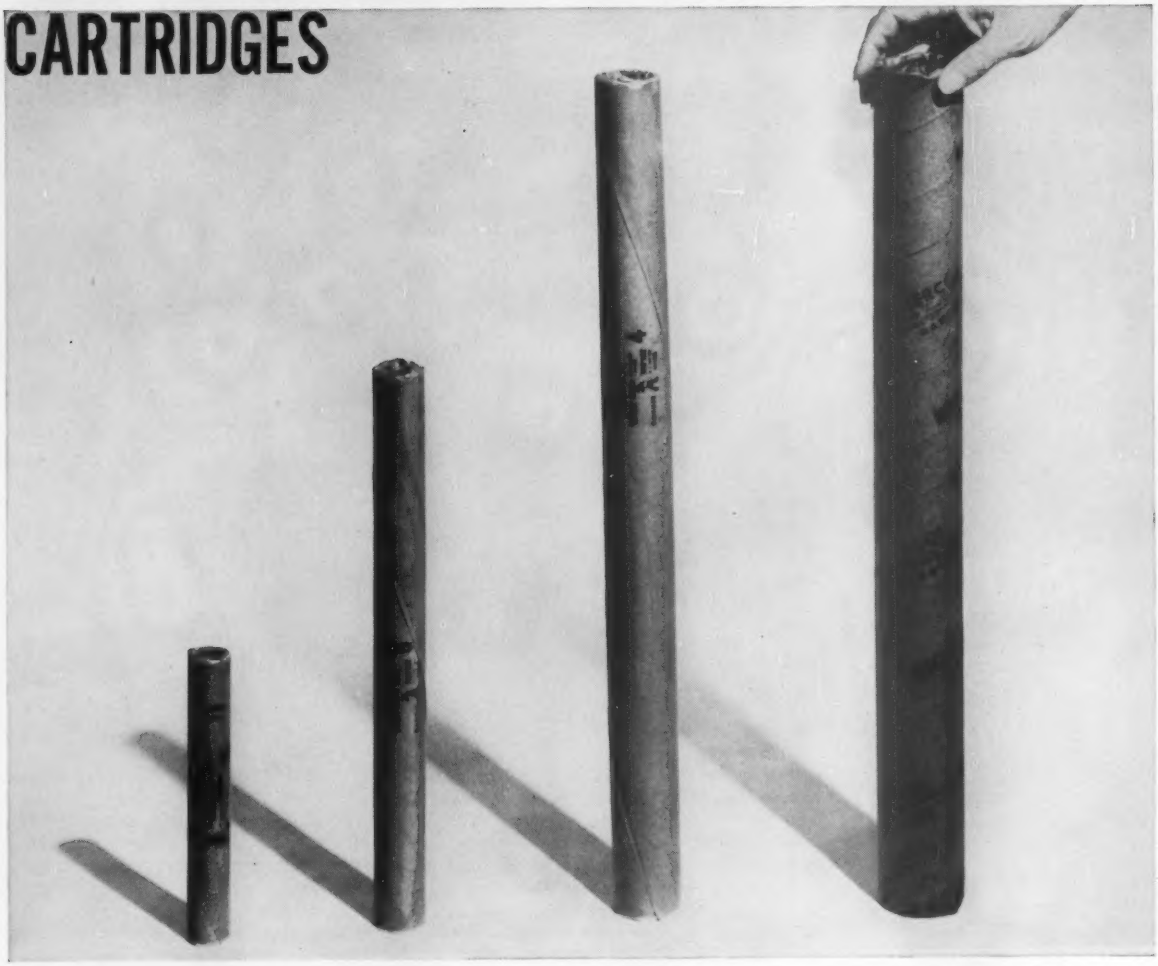

The Hercol series of low-cost, cap-sensitive, high-ammonia-content explosives are now available in cartridges of small diameters and standard lengths, as well as in the larger diameters and special packings.

The ability of Hercol to produce excellent fragmentation, its water resistance, Class 1 fumes, and high cartridge count—plus its low cost—have already been proved to the economy-minded quarry and open-pit operator.

Now that Hercol is manufactured in the smaller diameters, with Class 1 fumes, these same economies are available to the underground operator.

Contact the Hercules sales office nearest you or ask your Hercules representative for more detailed information on how Hercol can reduce blasting costs for you, too.

Properties of Hercol

	Hercol	Hercol 2	Hercol 4	Hercol 6
Fumes	Good	Good	Good	Good
Cartridge count—1¼ by 8-in. cartridges per 50 lb.	130	120	140	165
Cartridge diameter, in.	4 to 8½	1 to 3½	1 to 3½	1 to 3½
Weight strength, %	70	68	68	68
Cartridge strength, %	48	50	34	19
Water resistance	Fair	Good	Fair	Fair

A special grade of Hercol is formulated for seismic "pattern shooting" when the drill-holes are relatively dry.

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When the compressor stops operating, the receiver blows down automatically. This eliminates the possibility that the operator will forget and try to start the machine under load.

All portables have a safety circuit, but on most of them a broken wire will make the circuit inoperative. On Joy rotaries, the compressor cannot be operated unless the safety circuit is complete and working perfectly—eliminating a possible source of major compressor damage.

Every Joy rotary has an automatic drain system designed to prevent hydraulic lock. Standard equipment also includes a thermal bypass valve which prevents dry starts and eliminates moisture condensation.

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Foolproof features like these are standard factory equipment on all Joy rotary portable compressors—a complete line from 125 to 900 cfm.

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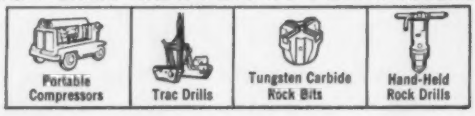

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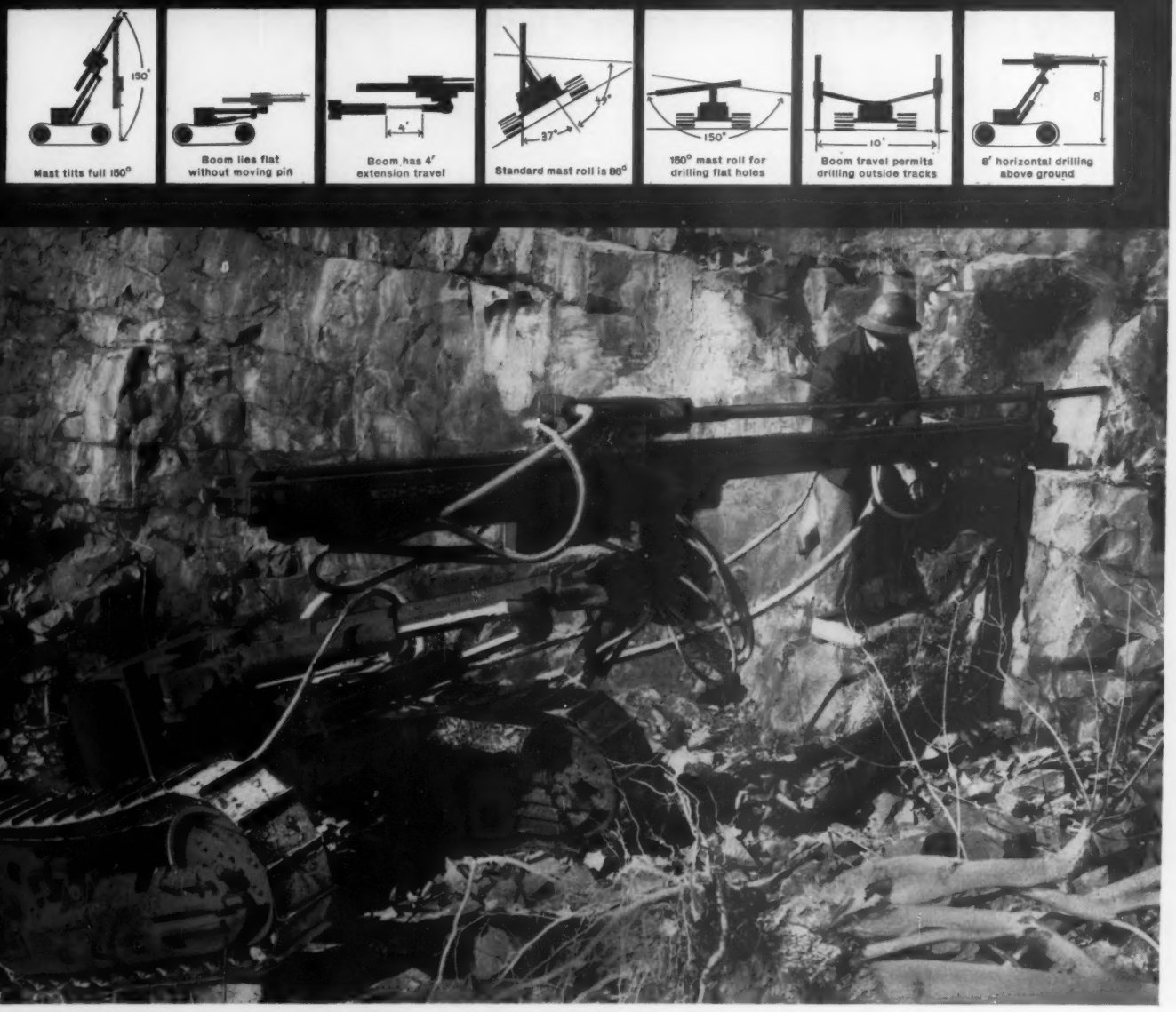

New Blue Brute 4½" Crawler Drill . . .

SLUGS FROM STRONGER STANCE

From crawler tread to striking bar, this new 4½" crawler drill is designed to get 5-10% more footage per drilling dollar. Its simpler construction, a more stable platform and easier control get more uninterrupted footage every drilling day.

Check out the all-new Blue Brute 4½-inch drill. It's built with the famous Worthington valve, the rugged rifle bar, heat-treated alloy-steel bushings at important wear points, and special analysis steel for *extra* strength. These and many other proven Worthington features mean least air consumption, less maintenance and downtime.

Look at the new Worthington mast! Five-inch channels and an all-welded assembly take full drill torque with strength to spare. And a more powerful feed motor shifts drill up and back more quickly for faster steel changes.

Look at the crawler carrier! An automatic line oiler is readily adjusted to lubricate drill, feed motor, hydraulic pump and tramming motors. The latter are 8 hp, giving a total drawbar pull of 6,000 pounds—enough to haul a 900′ compressor almost anywhere.

There's better operator safety, too! Carefully positioned boom and mast stops prevent over-balancing. And controls are placed for safer operation. But the basic stability of design permits the wide range of movements shown.

For more information about this new Blue Brute drill, call your Worthington rotary compressor distributor listed in the yellow pages. Or write Worthington Corporation, Dept. 60-29, Holyoke, Mass. In Canada: Worthington (Canada) Ltd., Brantford, Ontario.

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NEW Crawlmaster drill and Gyro-Flo compressor

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. . . instant safety torque release protects all drive components.

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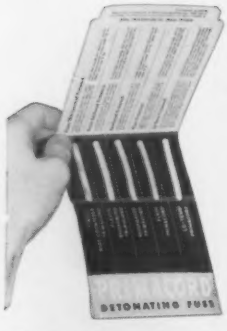

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